Marine Benthic Invertebrate Communities Near King County's Wastewater Outfalls

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Introduction

Marine benthic communities near King County's wastewater outfalls were studied as part of King County's National Pollution Discharge Elimination System (NPDES) monitoring to determine if discharges from the wastewater treatment plants are affecting the surrounding benthos. Marine benthic communities are studied because they spend most of their lives in direct contact with the sediment, and therefore are useful indicators of sediment quality. Metal and organic pollutants contained in sediments and sediment pore water could be consumed or adsorbed by the benthos, resulting in unhealthy animals, stressed communities, and the potential passage of these pollutants through the food web to other organisms.

Communities can be analyzed and characterized in many different ways. One of the most common methods is by looking at community diversity. Diversity is a measure of the complexity of the community structure, and is increased or decreased by physical, chemical, and biological factors. High diversity is generally good, as it indicates a balanced, stable, responsive community. Low diversity occurs in an area where the community is dominated by a few species, such as in a stressed area of high pollution, large and frequent disturbances, or anoxic sediments. Diversity indices are commonly used because of their ease of calculation, but are also criticized because of their lack of detecting community changes due to one environmental factor (Cao et al., 1996) and because they assume a normal community distribution (Tetra Tech, 1985). Many multivariate and biotic indices have recently become popular, but they require inferences about important information such as the feeding strategies of many organisms. Calculating abundances of pollution tolerant and pollution sensitive species is another useful method for examining community differences and determining factors influencing community structure. *Capitella capitata* is a polychaete widely used as an indicator of polluted, anoxic, or organically enriched sediments (Pearson and Rosenberg, 1978). The amphipod *Rhepoxynius abronius* and ophiuroids (brittle stars) have been used as indicators of clean, undisturbed sediments (Comiskey et al., 1984).

Benthic communities in this study were examined by calculating several diversity indices, calculating abundances, and determining community compositions. Significant differences were determined using analysis of variance (ANOVA) tests. Possible physical, biological and chemical environmental factors structuring the communities were also investigated.

Methods

Sediment samples were collected at multiple sites near the sewage treatment plant outfalls biannually from 1988 to 1996. Stations LSKQ04 and KSRK02 were sampled biannually from 1988 to 1994 and will be two of the stations investigated in this study. Station locations were slightly changed in 1996, so stations AL172N and WP215N were compared with LSKQ04 and KSRK02. Stations LSKQ04 and AL172N are located north of the Alki outfall, while stations KSRK02 and WP215N are located just north of the West Point outfall. Data collected in 1990 was not used for this community analysis because replicate samples were not recorded in a usable format. The month of sample collection varied annually, but was always either late summer or early fall.

Samples for benthic community analysis were collected with a 0.1-m^2 van Veen grab sampler. Five replicate samples were taken at each station in all years. Concurrent samples utilizing only the top 2 cm of sediment were collected for sediment grain-size distributions and total organic carbon (TOC) concentrations. Sediment collected for benthic community analysis was passed through a 1-mm sieve, and all retained organisms were collected, stored in fixatives, and stored for later taxonomic identification and enumeration. All animals were identified to the lowest possible taxonomic level, usually species, by taxonomic experts. After identification, the data set was reviewed and incidental catches, pelagic species, and colonial species were removed. Diversity indices and abundances were calculated with Excel 4.0 spreadsheets, and statistical analyses were performed with SPSS statistical software.

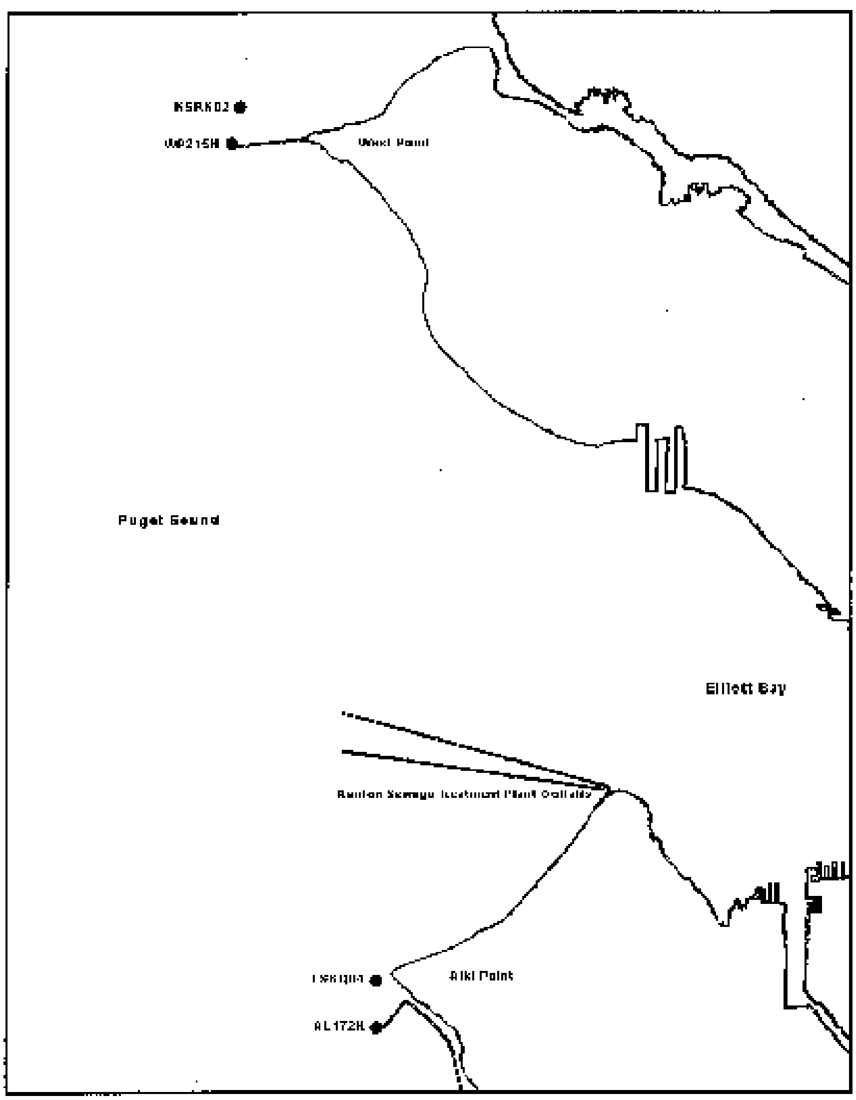


Figure 1. Map of all sample locations in King County, Washington.

Results

Diversity Indices

Three diversity indices were calculated to examine community changes over time for this study. The Shannon-Wiener diversity index (Valiela, 1984) was calculated with the following equation.

$$H' = \sum_{i=1}^{S} P_i \log_2 P_I$$

Where H' = Shannon-Wiener diversity index
P_i = Number of individuals in the i^{th} species
S = Number of species

Values ranged from 3.51 to 6.2 and averages are presented in Table 1. No significant differences were calculated at station LSKQ04, but the benthic community at station KSRK02 in 1994 was significantly less diverse than all other communities at that station.

Pielou's evenness index (Valiela, 1984) was also calculated for this study using the equation:

$$J = H'/\log_2 S$$

Where J = Pielou's evenness index
H′ = Shannon-Wiener diversity index
S = Number of species

Values for this index ranged from 0.42 to 0.89 and averages are presented in Table 1. The only significant differences discovered with this index were at both stations in 1994. The evenness index indicated that these two communities were less diverse than all others.

The final index used for community comparisons was Swartz's dominance index, which measures the number of species whose combined abundance comprises 75% of the total sample abundance. Values less than 5 usually indicate a stressed community (PTI, 1993). Average values ranged from 17.8 to 40.6 and are shown in Table 1. No differences were detected based on Swartz's index at station LSKQ04, but at station KSRK02 communities in 1988 and 1994 were significantly less diverse than communities in 1992 and 1996.

Table 1. Summary of diversity indices, abundances, and physical characteristics of all stations in all years. All indices and abundances are averages of five replicate samples.

	1988		1992		1994		1996	
	KSRK02	LSKQ04	KSRK02	LSKQ04	KSRK02	LSKQ04	WP215N	AL172N
Mean Shannon-Wiener	**5.02**	**5.50**	**5.86**	**5.85**	**4.35**	**5.69**	**5.89**	**5.60**
standard deviation	0.90	0.78	0.37	0.20	0.61	0.32	0.28	0.19
Mean Evenness	**0.85**	**0.86**	**0.87**	**0.81**	**0.46**	**0.64**	**0.88**	**0.87**
standard deviation	0.06	0.04	0.02	0.06	0.09	0.04	0.04	0.02
Mean Swartz's	**23.60**	**29.40**	**40.60**	**39.60**	**17.80**	**33.60**	**38.40**	**29.40**
standard deviation	9.24	10.41	10.01	5.98	6.26	3.65	4.28	4.51
Mean Total Abundance	**229**	**462**	**415**	**1255**	**835**	**502**	**462**	**342**
standard deviation	84	292	172	701	313	108	196	79
Mean # Species	**63**	**93**	**110**	**159**	**91**	**109**	**108**	**88**
standard deviation	23	40	26	47	15	14	22	9
Total Organic Carbon (mg/kg)	3800	1600	2100	4400	9840	4370	1310	1500
Depth (m)	89 m	35 m	95 m	66 m	95m	63m	78 m	50 m
Grain Size—% gravel	0.31	9.23	0.00	5.44	2.60	6.10	0.70	1.00
% sand	88.45	50.01	92.08	87.17	78.90	81.30	91.40	93.20
% silt	8.43	24.93	4.55	2.09	9.10	7.10	5.60	5.60
% clay	2.81	15.83	3.37	5.30	9.10	5.80	0.00	0.00

Abundances

Total average abundances ranged from 229 to 1255 and are listed in Table 1. Station KSRK02 in 1994 and station LSKQ04 in 1992 both had significantly higher abundances than all other communities. Averaged total numbers of species are also presented for each station in Table 1, and ranged from 63 to 159. The total number of species was significantly higher at LSKQ04 in 1992, but significantly lower in 1988 at station KSRK02. Abundances of the five numerically dominant species at each station are listed in Table 2. The types of numerically dominant species varied among years and between sites. The percent of organisms in each of the major taxonomic groups was calculated for each site and are presented in Figures 2 and 3. Except for station KSRK02 in 1994, the stations had very similar community compositions among years. This distribution among major taxonomic groups remained similar even though the dominant species varied among years.

Table 2. Abundances of the five numerically dominant species at each station for each year. Major taxonomic group and percent of the total sample abundance is given for each species.

Year	Station	Dominant Species	Taxonomic Group	Average Number of Individuals	Percent of Total Abundance (%)
1988	KSRK02	*Prionospio steenstrupi*	Polychaetea	36.2	15.8
		Spiophanes bombyx	Polychaetea	14	6.1
		Euphilomedes carcharodonta	Crustacea	11	4.8
		Macoma yoldiformis	Mollusca	6.6	2.9
		Polycirrus sp.	Polychaetea	6.2	2.7
1992	KSRK02	*Ampharete acutifrons*	Polychaetea	53.2	12.8
		Pectinaria californiensis	Polychaetea	15.4	3.7
		Proclea graffii	Polychaetea	14.6	3.5
		Paraprionospio pinnata	Polychaetea	14.2	3.4
		Bittium attenuatum	Mollusca	11.4	2.7
1994	KSRK02	*Golfingia minuta*	Sipuncula	331.4	39.7
		Erichthonius sp.	Crustacea	28.8	3.5
		Polydora sp.	Polychaetea	26.4	3.2
		Caprella mendax	Crustacea	21.2	2.5
		Megacrenella columbiana	Mollusca	17.6	2.1
1996	WP215N	*Hiatella arctica*	Mollusca	50.2	10.9
		Neosabellaria cementarium	Polychaetea	31.4	6.8
		Pholoides asperus	Polychaetea	13.4	2.9
		Byblis millsi	Crustacea	12.2	2.6
		Dipolydora akaina	Polychaeta	11.8	2.6
1988	LSKQ04	*Euphilomedes carcharodonta*	Crustacea	34.2	7.4
		Tritella pilimana	Mollusca	35.75	7.7
		Pholoides aspera	Polychaetea	18.8	4.1
		Prionospio steenstrupi	Polychaetea	14	3.0
		Spiochaetopterus costarum	Polychaetea	13.8	3.0
1992	LSKQ04	*Pholoides aspera*	Polychaetea	177.2	14.1
		Phyllochaetopterus prolifica	Polychaetea	105	8.4
		Phoronopsis harmeri	Phoronida	42.8	3.4
		Ericthonius sp.	Crustacea	32.6	2.6
		Heteronemertea	Nemertea	28	2.2
1994	LSKQ04	*Caprella mendax*	Crustacea	40.6	8.1
		Peisidice aspera	Polychaetea	29	5.8
		Phyllochaetopterus prolifica	Polychaetea	28.8	5.7
		Erichthonius sp.	Crustacea	26.6	5.3
		Sabellidae	Polychaetea	24.6	4.9
1996	AL172N	*Tritella pilmana*	Crustacea	32.4	9.5
		Aoroides sp.	Crustacea	27.4	8.0
		Cucumaria piperata	Holothuroidea	19.6	5.7
		Caprella mendax	Crustacea	13.2	3.9
		Lumbrineris californiensis	Polychaeta	13	3.8

Figure 2. West Point

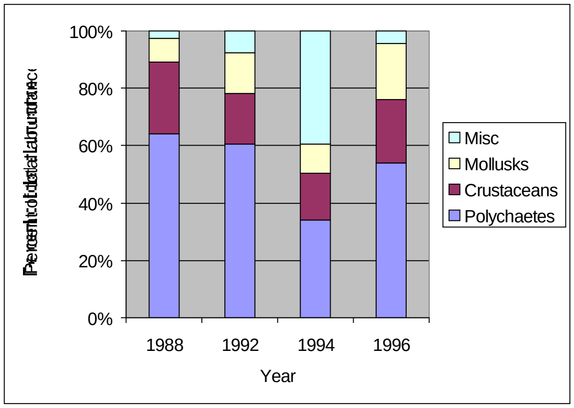
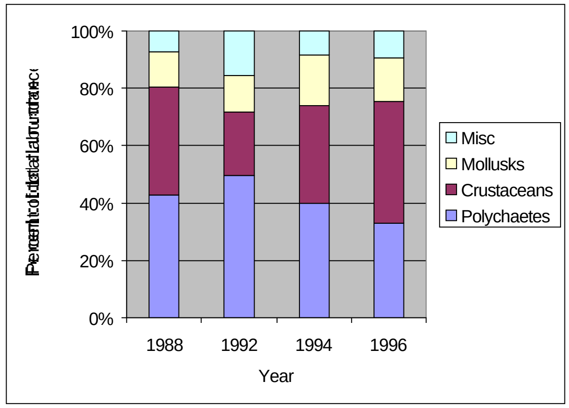


Figure 3. Alki Point



Figures 2 and 3. Percentage of organisms in each major taxonomic group at stations KSRK02 (left) and LSKQ04 (right). Percent of organisms based on averages of five replicates.

Discussion

Stations KSRK02 and WP215N, West Point

All diversity indices and total abundances indicated that stations KSRK02 and WP215N in 1994 were less diverse but had more individual organisms than all other years. This is due to the large number of sipunculan worms, *Golfingia minuta*, recovered in 1994. These surface-detritus feeders are only a few mm long and like to occupy vacant foraminifera tests (Barnes, 1980; Kozloff, 1990). *Golfingia minuta* could be present in high abundances because of patchy distributions of the animal, larval recruitment patterns, food availability, or many other physical and biological factors. Variability of station location because of different location methods (Loran and GPS) is another possible source of community variation. Future sampling should investigate this species to track further population fluctuations and explore possible explanations.

No significant correlation between diversity indices and physical factors were detected at the West Point stations. However, a weak correlation was observed between all diversity indices and total organic carbon values, indicating that this is a possible factor controlling and structuring the communities. Not including the stations in 1994, the numerically dominant species varied among years, yet the percent of organisms in each of the major taxonomic groups remained very similar. This could indicate that the overall environment is relatively stable and maintains a constant community composition from year to year, yet small variations produce different numerically dominant species. These variations could include larval recruitment, food type and amount, species interactions, water temperature, sediment grain size, dissolved oxygen concentrations, and variability of station location. *Capitella capitata*, a pollution-tolerant polychaete worm, was not recovered at this station in any year. Conversely, Ophiuroids (brittle stars) are considered a pollution-sensitive species and were recovered at this station in all years. This indicates that the environment near the wastewater outfall at West Point is unpolluted enough to support a pollution-sensitive invertebrate.

Stations LSKQ04 and AL172N, Alki Point

Total abundance and number of species at stations LSKQ04 and AL172N in 1992 were significantly higher than in all other years. However, no differences were identified among diversity indices. This indicates that the communities are stable, yet responding to possible variations in food availability, larval recruitment, total organic carbon concentrations, and sampling station location. Abundances also could have been higher because the samples in 1992 were collected in late August, and in all other years samples were collected from mid-September to October.

A weak correlation was seen at this station between diversity values and total organic carbon, indicating that total organic carbon may be a factor structuring the benthic communities. The numerically dominant species varied among years, but the percent of organisms in each of the major taxonomic groups remained quite similar. This is the same situation observed at the West Point stations, and the same possible explanation applies here. The occurrence of pollution-tolerant and pollution-sensitive species, *C. capitata* and ophiuroids, was the same as at the West Point stations, and the same possible explanations also apply here.

Conclusions

Total organic carbon concentrations may be a factor structuring the benthic communities, because stations displayed a weak correlation of higher diversity values with decreasing total organic carbon. Factors structuring communities may be easier to detect with a greater number and a greater diversity of sampling locations. Other possible controlling factors include sediment grain-size distributions and dissolved oxygen concentrations.

Future studies would be enhanced by the collection of a reference site away from the sewage outfalls. This would allow for effects from the treatment plant outfalls to be determined more effectively. Suitable reference sites are difficult to find because variations in physical environmental parameters, sediment chemistry, natural fauna interactions, and seasonal conditions can result in very different benthic communities. Care should be taken when selecting a reference site; in fact, several references may need to be sampled to accurately compare to the study sites.

Based on the information gathered in this study, the benthic communities near King County's wastewater outfalls are probably not affected negatively by wastewater discharges, because the communities do not show dramatic changes in diversities or abundances over time. This can not be determined conclusively from this study, since only one station was sampled near the treatment plant outfalls, so effects around the outfall pipe could not be determined. Future benthic studies will utilize a very different station arrangement, and will allow gradient effects away from the outfalls to be investigated. Continued monitoring of these communities will remain a part of the NPDES permit, but monitoring is also essential to track long-term changes, to determine the health of the communities, and to further investigate which factors act to structure and control the communities.

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